Appendix D
Engineering Calculations Supporting Control Device Performance

The Siemens Water Technologies, Inc. (SWT) Parker, Arizona facility operates three carbon adsorbers (WS-1, WS-2, and WS-3), which will treat the vapors from the spent carbon storage tanks, recycle water tank and furnace feed tank. WS-1 treats vapors from spent carbon storage tanks T-1, T-2, T-5, T-6 and T-9. WS-2 treats the vapors from hoppers H-1 and H-2. WS-3 treats vapors from furnace feed tank T-18. These control devices have been designed as follows:

DESIGN PARAMETER	WS-1 (T-1,2,5,6,9)	WS-2 (H-1, H-2)	WS-3 (T-18)
Maximum Flow Rate (cfm)	115	2500	5.9
Inlet Benzene Concentration (ppmv)	4,540	4	4,540
Relative Humidity (%)	50%	50%	50%
Temperature	Ambient	Ambient	Ambient
Type of Carbon	Granulated Activated Carbon	Granulated Activated Carbon	Granulated Activated Carbon
Capacity of Carbon Canister (lbs.)	4000	4500	1000
Working Capacity of Activated Carbon	30%	6.5%	30%
Source Operating Schedule	Continuous	Continuous	Continuous
Theoretical Design Control Efficiency (%)	100	100	100
Design Carbon Replacement Period (Days)	7.88	100	38
Theoretical Outlet Benzene Concentration (ppmv)	0	0	0

Calculations and technical data to support the above design parameters are provided below:

Flow Rate

The flow rates to WS-1 and WS-3 are based on the actual observed maximum flow rates. The maximum daily flow rates used in the calculations below more accurately reflect maximum conditions anticipated during the life of each carbon bed. The flow rate to WS-2 is based on the capacity of fan that pushes the vapors to the control device.

Inlet Benzene Concentration

The inlet vent stream composition consists of air, water vapor, and entrained hydrocarbon from the spent carbon received at the facility. In preparing this analysis, it is assumed that the total hydrocarbon concentration of the spent carbon can be as high as 30%, and that the maximum benzene concentration can be as high as 15%.

The inlet benzene concentration for WS-1 is calculated assuming that all of the benzene absorbed by the water in contact with spent carbon is liberated in the spent carbon storage tanks. Using the attached isotherm, a 15% benzene concentration in the waste would correspond to a 30 ppmw (mg/l) concentration of benzene in the water. The inlet benzene concentration is determined for WS-1 as follows:

- Determine the amount of benzene being liberated from the water in the spent carbon storage tanks.

  $\mathbf{B_{WS1}}$ = $(FR)(C)(WF)(28.32\ L/ft^3)(2.2 \times 10^{-6}\ lb/mg)\ (60\ min/hr)$

  where:

  $\mathbf{B_{WS1}}$ = Amount of Benzene Directed to WS-1 (lb/hr)
  FR = Amount of Slurry Being Added to the Tanks or Vapor Directed to WS-1 (cfm)
  C = Concentration of Benzene in the Water (30 mg/L)
  WF = Fraction of Water by Volume in the Slurry(0.50)

  $\mathbf{B_{WS1}}$ = $(115\ cfm)(30\ mg/L)(0.5)(28.32\ L/ft^3)(2.2 \times 10^{-6}\ lb/mg)(60\ min/hr)$

  $\mathbf{B_{WS1}}$ = 6.448 lb/hr

- Determine the concentration of benzene (ppmv) being liberated to WS-1**.**

  $$\mathbf{CONC} = \frac{[(B_{WS1}) / (MW_B)](1{,}000{,}000)]}{[(FR)(60\ min/hr)] / (MVOL)]}$$

  where:

  CONC = The Inlet Benzene Concentration to WS-1 (ppmv)
  $\mathbf{B_{WS1}}$ = Amount of Benzene Directed to WS-1 (lb/hr)

MW_B = Molecular Weight of Benzene (78.12 lb/lb-mol)
FR = Vapor Flow Rate to WS-1 (cfm)
MVOL = Molar Volume of Gas (379 ft^3/lb-mol)

$$\textbf{CONC} = \frac{[(6.448\ \text{lb/hr}) / (78.12\ \text{lb/lb-mol})](1{,}000{,}000)]}{[(115\ \text{cfm})(60\ \text{min/hr})] / (379\ \text{ft}^3/\text{lb-mol})]}$$

CONC = 4,534 ppmv

For calculation purposes, the concentration of benzene is assumed the same at WS-1 and WS-3.

The maximum inlet benzene concentration at WS-2 is assumed to be 4 ppmv. This is based on organic vapor analyzer (OVA) data collected at the site. To be conservative, all hydrocarbon detected is assumed to be benzene.

Working Capacity of the Activated Carbon

The working capacity of the carbon is determined using the attached isotherm. This isotherm indicates that the working capacity of WS-1 and WS-3 is approximately 30% for benzene. For WS-2, the working capacity is approximately 6.5% for benzene.

Design Replacement Period

The design replacement period is calculated using the following equation:

$$\mathbf{Y} = \frac{(ACgac / 100)\ (Wgac)}{[(Ci - Co) / 10^6](Qf)(D)(1440\ \text{min/day})]}$$

where:

Y = Carbon Bed Life (days)
ACgac = Adsorption Capacity of Carbon for Benzene (wt. %)
Wgac = Mass of Carbon Bed (lb)
Ci = Inlet Concentration Benzene (ppmv)
Co = Outlet Concentration Benzene (0 ppmv)
Qf = Gas Flow Rate Through Adsorber (cfm)
D = Density of Benzene (0.2028 lb/ft^3)

- Calculate the design carbon replacement period for **WS-1** using the above equation.

$$\mathbf{Y} = \frac{(30 / 100)(1000\ \text{lb})}{((4540 - 0) / 10^6)(115\ \text{cfm})(0.2028\ \text{lb/ft}^3)(1440\ \text{min/day}))}$$

$$Y = 7.88 \text{ days}$$

- Calculate the design carbon replacement period for **WS-2** using the above equation.

$$Y = \frac{(6.5 / 100)(5000 \text{ lb})}{((80 - 0) / 10^6)(2500 \text{ cfm})(0.2028 \text{ lb/ft}^3)(1440 \text{ min/day}))}$$

$$Y = 100 \text{ days}$$

- Calculate the design carbon replacement period for **WS-3** using the above equation.

$$Y = \frac{(30 / 100)(1000 \text{ lb})}{((4534 - 0) / 10^6)(5.9 \text{ cfm})(0.2028 \text{ lb/ft}^3)(1440 \text{ min/day}))}$$

$$Y = 38 \text{ days}$$